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How adjustments in land use patterns contribute to drought risk adaptation in a changing climate—A case study in China

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ABSTRACT

In the context of climate change, adaptation to climatic extremes, such as drought, has attracted worldwide attention, yet many practical adaptation strategies need to be examined at the local level. Based on a case study of the village of Beidian, located in a drought-prone region in northern China, this study demonstrates that when faced with multiple pressures of regional climate change, drought risk and rural poverty, reasonable adjustments in land use patterns can serve as an effective adaptation strategy in the agricultural sector. We used household questionnaires, in-depth interviews with village managers, and land use surveys at the farming plot level to quantify the relationship between land use change and drought mitigation effects. Our findings indicate that in the past decade, the farming practices in Beidian have transformed from a complete reliance on the winter wheat–summer corn rotation to a new diversified mode of apple as the main crop and corn and coarse cereals as the subsidiary crops. The current farming mode is proven to possess a stronger adaptive capacity to drought due to its higher water-saving efficiency and economic benefit, which facilitates rural poverty reduction and socio-economic development. This study presents a feasible approach to address adaptation strategies at the local level, which provides policymakers with information on how to best support farm-level adaptation and to reduce farmers' vulnerability to climatic extremes within the broader context of climate change.

Introduction

Globally, drought is one of the most widespread and prolonged environmental hazards, and it frequently causes sizeable agricultural losses, especially in less-developed countries with economies that are highly dependent on agriculture. Over the past several decades, nearly half of the world's countries have suffered from drought (UNDP, 2004). Even worse, it is likely that a changing climate may increase the possibility and severity of drought (IPCC, 2007). Therefore, managing the risks of an increased frequency and magnitude of drought is an important global challenge (IPCC, 2012). China has the world's largest population and a large and critically important agricultural sector. Its frequent, spatially extensive, and lasting droughts cause serious losses to the agricultural economy (Lei et al., 2011). Particularly in northern China, recurrent droughts have afflicted the rural population and threaten regional food security. Droughts may cause crop damage, low productivity and high production costs (Alam et al., 2012), which lead to income loss for farmers, increased poverty levels and an aggravated seasonal unemployment rate (Siwar et al., 2009). Exploring strategies for mitigating and adapting to increased drought has thus become a critical issue for rural poverty reduction and sustainable development.

Adaptation, a concept widely used in the human dimensions of climate change research, refers to the process of adjustment to actual or expected climate and its effects to moderate harm or to exploit beneficial opportunities (IPCC, 2012). In the face of intractable natural disasters, such as droughts and floods, White (1945) argued that instead of trying to control nature, society needs to learn to live more compatibly with the natural occurrence of disasters. The notion of risk management should shift from trying to control change to a more realistic viewpoint aimed at enhancing the capacity of social–ecological systems to adapt to uncertainty (Holling, 1973; Adger et al., 2005; Adger, 2006). Confronted with increasing drought stress and water scarcity due to climatic

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variation and change, adaptation to droughts in a changing climate has been a global challenge and a key scientific focus of climate change science.

Agricultural land use and farmers' planting practices are some of the most concentrated relationships between human and nature. Examining how to effectively adapt to agricultural drought by means of reasonable adjustments in land use should be a preferred approach in research on drought adaptation. In particular, with the emergence of land change science in the academic domains of global environmental change and sustainability (Turner et al., 2007), the role that land use change might play in disaster risk mitigation has been addressed in various ways. For example, research suggests that inappropriate land use practices may intensify droughts (UN/ISDR, 2011). In contrast, rational land use planning, such as reasonable layout of the distribution of farmland, can play a positive role in mitigating natural disasters (Tang et al., 2008; Bryan et al., 2009). In Malaysia, paddy farmers need to adjust their land use patterns (Alam et al., 2012) to cope with climate change, including use of different crop types and varieties, changing sowing time, and planting more trees.

These studies indicate that adapting to climate change and its attendant drought by adjusting land use is an important strategy in the agricultural sector. However, they have largely been based on theoretical arguments and qualitative evaluation. Quantitative analyses, particularly empirical case studies on the relationship between land use patterns and drought severity, are rare. In other words, little is known about what types of land use patterns can effectively not only help reduce regional vulnerability to drought, but could enhance local resilience and adaptive capacity to potential drought risk. To answer these questions, more empirical studies, particularly at the rural community level, are required.

Based on a case study in the drought-prone northern China, this study attempts to detect the farm-level land use changes and to quantitatively analyze how these changes contribute to drought risk mitigation and socio-economic development. We collect first-hand data through household surveys, in-depth interviews with local managers, and land use surveys at the farm level. We assess the effectiveness of land use adjustments in terms of mitigating drought risk and facilitating farmers' livelihood improvement. We tentatively develop a conceptual model of drought risk adaptation and discuss its broader implications in terms of socio-economic sustainability.

Materials and methods

Study area

The village of Beidian, with an area of approximately 350 hm^2, is located in the drought-prone Xingtai County in northern China's Hebei Province (Fig. 1). The annual precipitation is approximately 500 mm but the annual evaporation is above 1600 mm, making the area very sensitive to drought. In addition, its seasonal and inter-annual fluctuations in precipitation are striking. For instance, total rainfall was 799 mm in 2001 but only 352 mm in 2002, indicating obvious climatic variation.

Beidian Village traditionally adopted a farming mode of winter wheat–summer corn rotation in order to produce enough food for the villagers. However, with scarce annual rainfall and the uneven distribution of seasonal precipitation, local agricultural production relies heavily on ground water irrigation to supply the high water needs of crops such as winter wheat. If any year has inadequate groundwater due to drought, local agricultural production is prone to losses in yield. In particular, during the continuous dry period of the late 1990s, drought-induced losses consistently threatened regional grain security, which in turn damaged local farmers' income and livelihood.

In the past decade, the Chinese government carried out a reforestation program known as "Grain for Green" (GfG) (Zhou et al., 2009) to increase forest cover and prevent soil erosion, which has resulted in notable land use changes nationwide. In Beidian Village, a large proportion of previous wheat–corn rotation farmland was gradually replaced by apple trees based on the suggestion of agricultural expert, who carefully considered the suitability of water, soil, climate, and other environmental factors in agricultural production. Interestingly, along with changes in land use patterns, the impact of droughts on local agriculture alleviated noticeably. However, it is not clear how changes in land use patterns relate to alleviating the impacts of drought. We need to conduct an in-depth field investigation to answer this question.

Field studies

Field survey and household interview are important approaches in research on climate change adaptation and disaster risk reduction, particularly at the local level (Bryan et al., 2013; Raymond and Robinson, 2013). They can provide reliable local knowledge (Raymond et al., 2010) and first-hand information for decision makers by revealing farmers' actual needs and the specific adaptation measures they have taken.

In-depth interviews with the village managers and senior villagers

This study first conducted face-to-face interviews with the current and former village managers to obtain an overall understanding of the village conditions. Second, all of the villagers older than 70 (there were 11 in this village) were selected as key informants for providing historical information about the village's development. The open-ended questions for village leaders and the senior villagers focused mainly on the overall situation in this village. The questions included (1) How have drought disasters affected local agriculture in historical periods? (2) Did the groundwater level fluctuate in different years and seasons? (3) What were specific measures taken by the villagers to mitigate the drought impact? (4) How has local land use changed over recent decades, particularly since the implementation of the GfG program?

Household questionnaires

Semi-structured questionnaires were carried out with farmer households aimed at exploring the true impacts of climate change and drought on local agriculture, and collecting first-hand information on farmers' agricultural production and adaptation actions to drought. We interviewed 55 householders from the total 105 farmer households of Beidian using a stratified random sampling approach that covers different income levels. Farmers were asked questions concerning the detailed information on agricultural production, and their incomes from both on- and off-farm activities. In particular, based on designed questionnaires, we recorded the inputs (including seeds, fertilizers, pesticides, irrigation, and machinery) and the outputs (both yield and market prices) of local crops such as wheat, corn, and apples in recent years.

Survey and measurement of micro land use change

Since land use in Beidian has experienced a striking change in recent years, detecting and measuring the details of land use change, especially at the farm plot level, is an essential step for understanding farmers' adaptive processes. A Google Earth satellite image with high spatial resolution enabled us to detect small-scale land use pattern. The satellite data used in this research were downloaded from Google maps: http://maps.google.com/ (recorded on October19, 2009 from GeoEye satellite). Since Google maps do not provide land use change information, they were mainly used to